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As for graduate students it seems to me that since they are presumably mature individuals with thorough preliminary training in the main zoological subjects, one of the important things to do is to wean them away from mere course taking, a habit with which they are usually obsessed, and head them into problems and seminaries. If their preparation is inadequate let them take courses open to advanced undergraduates but strictly graduate courses can, I believe, be advantageously restricted to a few lectures per week in various special fields.

Being mature, the graduate student may well be expected to get much of his information by reading for himself. By way of suggestion I would give him a memorandum to the effect that it goes without saying that in addition to his more technical pursuits, every candidate for the doctorate will be expected to know modern evolution problems; the generally accepted views on phylogenetic relationships and the validity of the criteria on which these are based; and the elements of animal behavior, genetics and developmental mechanics. A suitable list of special references for study in these fields would be appended.

Furthermore, for the purpose of broadening his interests and cultivating a sense of proportion, each candidate might advantageously be given a list of fifty or more books that he is expected to have read before he completes his work. This list would include mainly the general classics of the subject in various departments, such as voyages, travels and explorations; history; biography; a few special memoirs; general principles; a few works of the better literary naturalists; and some of the more general works in special fields.

In conclusion I should say, then, that I see no need of abandoning our general zoology, comparative anatomy, invertebrate zoology, embryology and histology courses in favor of the newer biological sciences, though we can perhaps advantageously shorten them to make room for courses in the new subjects and we can pervade them all more or less with the method and thought of the newer work. If in these fundamental courses we will but put life back into our laboratory specimens, life into our method of offering them as subjects for thought, and life into our students by forcing them into the interpretative attitude of mind, then I think we shall have gone far toward introducing our charges to much that is significant in the newer fields without sacrificing the well-recognized values of the older discipline.

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FROM THE STANDPOINT OF A BOTANIST

THOSE of us who are possessed of a conservative temperament may be inclined to look askance at the newer fields of investigation, or to doubt their value for educational purposes. If so, we need merely to consider that not many years ago science of any kind was not regarded as a suitable subject for school or college. Moreover, the sciences themselves have undergone a marked evolution. The earliest biological studies were descriptive and enumerative; then came the study of internal structure, followed in its turn by the study of function, environment and inheritance. To an outsider it looks as though the subject of entomology were still largely in the taxonomic stage of development, which is not to be wondered at when one recalls that over half the species of animals are insects.

Instruction in biology has likewise exhibited an evolution; it no longer consists wholly or even largely of systematic work. Botanists still do a certain amount of "manual labor," but fortunately we have passed out of the period when first-year

botany consisted in a study of Gray's Manual, and the second-year botany of more Gray's Manual. Botanists have traveled a long way from the ideal of Linnæus, who declared that the only worthy task of a botanist is to know all the species of the vegetable kingdom by name. Thus progress has been the word in biological teaching, but, as has been the case in education in general, fads have crept in and have usurped the place rightly belonging to less spectacular but more fundamental aspects of the subject. One of the most pernicious of these in the recent history of botanical instruction is indicated by the flood of elementary text-books on so-called practical botany, in which there is very little botany, but a good deal of elementary forestry, horticulture, plant breeding and the like.

Since all of us specialists are faddists in a more or less worthy sense, we run the risk of introducing our favorite topics into our courses, and even giving them undue prominence. Moreover, we may experiment on the matter and method of our courses, while quite alive to the danger of riding our hobby in the lecture room. It will probably be agreed that the course which is most important from the standpoint of pedagogic experiment is the introductory course—general biology or general botany or general zoology, as the case may be. In fact it may be said that the crux of the question lies here, for if it can be decided what is to be the content of this general course the more advanced courses will readily fall into line; the character of the latter will be largely determined by the special needs in the particular institution; for instance, the course in plant pathology which would be required in a college of agriculture would naturally be represented in a less technical institution by an advanced course in fungi. Further, the general course includes all the biology which many students get, hence this course should be organized with particular care.

Coming then to the consideration of the general course, a study of curricula shows that there is a marked lack of unanimity among biologists as to what should be its content, and this fact causes no surprise, but is entirely reasonable in view of the diversity in needs of students. The lack of uniformity which courses exhibit arises from selection of material, for in a field so vast one can scarcely hope to treat the whole, even in a general way. If such should be attempted, we encounter at least two dangers: first, a topic must be treated so briefly that students fail to comprehend it. Any one who has tried to make Mendel's law clear to a freshman class will appreciate this statement. Second, when the student begins more advanced courses he loses the advantage of entering distinctly novel fields—we have already sucked the juice out of the orange, so to speak. But if the whole subject may not be covered, it becomes necessary to select, and continued selection through a period of time has resulted in the survival of the fittest, that is, the assembling of a number of topics which may be regarded as fundamental. These topics in a well-ordered course represent principles, for the plants or animals studied are not introduced for their own sake, but in order to illustrate one or more principles which it is desired to teach. Thus a liverwort may not be of great importance on its own account, but it illustrates alternation of generations and the probable origin of a land flora, and hence properly finds a place in a general course.

When a new field of discovery supplies facts which make a claim for introduction into the general course, they must justify the claim, lest we crowd out the tried and proved to make room for the new. The significance and value of a new fact may

be tested thus: how does it react on the already ascertained body of facts? Does it essentially modify what we have come to regard as fundamental concepts? The answer to these questions will go far in determining whether a new fact or theory shall find a place in a general course. Judged by this criterion, paleobotany has won for itself a place in any course where the relationships between plants constitutes one of the fundamental principles. Not that paleobotany needs to be introduced formally under that designation, but fossil plants may now be dealt with in an evolutionary scheme in the same way as existing ones, and our view of the plant kingdom as a whole is correspondingly broadened. To quote D. H. Scott: "Our whole conception of two at least of the great divisions of the Vegetable Kingdom—the Pteridophyta and the Gymnosperms—and of their mutual relations, is already profoundly influenced by the study of the ancient forms." In a similar way recent progress in plant anatomy has so far established a new point of view that its results must be incorporated in all but the most elementary presentation of the subject of morphology.

But there are other ways in which a new topic may justify its claim for insertion in a general course. The new facts may have such intrinsic and fundamental importance that they may fitly find place in a course, although not reacting to any considerable extent on the older material. In this way the leading facts concerning inheritance may justify the place they hold in some general courses. A real difficulty in including this topic arises from the fact that freshmen lack the antecedent training in cytology and embryology which is desirable before one can really grasp the principles of heredity.

A principle which must not be lost sight of in deciding for or against a new topic is its pedagogic value. New subjects suffer in this respect from their lack of organization; they consist largely of a number of interesting and significant observations, but these are at first unrelated, and therefore of inferior value for teaching purposes. A good example is seen in the mass of facts which is accumulating as the result of the activity of workers along Mendelian lines. It has also been noticed that speculation has run far in advance of these facts —an observation which carries its own moral. Plant ecology is another branch of the subject which lacks organization. As Cowles has said, until recently ecology had no fundamental concepts. Moreover some of the workers who have rushed into this field have not hesitated to provide a plausible explanation for every phenomenon, with the result that careful work has been discredited along with the hasty. We should beware of the attitude of mind which leads us to explain everything. We have abundant reason to consider this matter of pedagogic value, for we must realize that sciences and especially the biological sciences are still on trial as subjects suitable for schools and colleges, and that some disappointment has been manifested at the results following their introduction. All sciences still suffer from a lack of the definite organization which has long been possessed by the classics and mathematics. Biology is indulgently tolerated by the followers of the more exact sciences; in the words of one of my engineering colleagues, "biology is largely an observational subject." Hence we do well to be sparing in our introduction of new and unorganized branches of our subject. We are in danger of sacrificing a training in exact thinking, such as is provided by comparative morphology, and gaining only intellectual haziness. That this is a prevalent and serious defect in American education is

borne out by the report of Oxford tutors concerning Rhodes scholars; the tutors readily admit the mental alertness of the American scholars, but uniformly remark upon their inability to settle down to do a long spell of thorough work.

Again, since we very properly lay more stress on nature than on books, the availability of a new topic for laboratory purposes must be considered. It is a matter of common experience that morphological work presents fewer difficulties than any other when unwieldy classes have to be marshalled section after section in overcrowded laboratories. Unless numerous assistants and abundant laboratory and greenhouse space are available, work along physiological, ecological or genetic lines is apt to result in much waste of time and few profitable results, while at the same time the student is missing the opportunity of laying a stable morphological foundation for his later studies.

Even when the best word has been said in behalf of the newer fields, the preeminence of morphology as the *sine qua non* of instruction remains untouched. Though the educational pendulum may swing far to the right and left, it returns to its stable position, and that position points to morphology. One of the dangers which a student encounters is that of specializing too early, before he has laid a solid foundation. Hence our general course must show a preponderance of that branch which experience has shown to be fundamental. Examples of the fatal consequences of an absence of adequate knowledge of morphology are not hard to find. On the botanical side we need only recall the blunders of the earlier paleobotanists, who framed phylogenies based on external structures only, and in our own day we have the sorry spectacle of experimental morphologists who have a slender grasp of morphology, and of plant physiologists who propose theories which are at once seen to be untenable when viewed in the light of the elementary facts of histology. Work in genetics or in plant pathology carried on by those who are not rooted and grounded in morphology is bound to be of the empiric type, too greatly resembling the product of the short courses in agriculture.

What then shall be the nature of the well-ordered general course? Since a paper such as this is more or less the writer's confession of faith, I may as well conclude by telling what we are attempting to do in the institution which I represent. First, the course is one in general *biology,* in which the professors of botany and zoology lecture in turn, each completing a topic before giving place to the other. During the greater part of the year the morphology of the two kingdoms is developed, but each form selected for study is considered not on its own account, but is introduced in order to illustrate some fundamental principle. Form and function go hand in hand, each supplementing the other. Thus the course is strung on an evolutionary and also a physiological thread. Any form which does not fit in with this scheme is ruthlessly weeded out. At suitable times general topics such as evolution, heredity and certain ecological themes are formally treated. Laboratory work for the most part follows the order of topics adopted in the class-room, but while human physiology is being considered in the class-room the class is dissecting the frog in the laboratory.

Realizing that it is somewhat presumptuous for one man to speak for all botanists, I have sought the opinion of a botanist who has had long experience in teaching, Dr. John M. Coulter, and have been pleased to find that his view of the subject matter of an elementary course pretty closely cor-

responds with the one expressed in the foregoing. I take the liberty of quoting:

I should say that the elementary course or courses in botany should always be synthetic. Fundamental in the synthetic presentation of botany I should say is morphology, for I do not believe that any effective work can be done without some knowledge of the structures involved. Then I should say that the morphological thread that runs through the course should string together the most important physiological phenomena as explanations of morphological structure. In fact, I would not regard any morphology as significant that could not be explained in terms of physiology; and on the contrary, I would not regard any physiology as worth while that could not be fitted into morphological structure. In other words, I can not divorce the machine from its work. Naturally in this statement ecology becomes merely a form of physiology. This would be my general notion as to the content of an elementary course in botany.

What should be given afterwards depends entirely upon the size of the botanical staff and its differentiation in interest. After the synthetic course, I think there should be opportunity to develop morphology, physiology, ecology, etc., independently. Of course, experimental morphology should come in as a hybrid between morphology and physiology. I should say that genetics would come after almost everything else.

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EXPERIMENTALISM IN ZOOLOGY

THE followers of science have shown at all times a marked disposition to readjust the style of their intellectual apparel to new conditions, and in this respect the zoologist is no exception. There are some among us who still prefer to appear in the ancient and respectable mental garb of the systematist, others who adorn themselves in the Empire costume of the comparative anatomist, and still others who have put on the Victorian attire of the embryologist. But he who wishes to be truly modern is content to clothe himself in only the scanty raiment of the experimentalist. A glance at this last class shows it to be made up of the young and the would-be-young. This latest style, unlike its predecessors, is not a creation from Paris or from London, but is largely a home-product, the result of what its inceptors would call internal factors, those conveniently vague things about which we know so little. Although we are not wholly clear as to the process by which we have come to be experimentalists, we are convinced that it depended upon something like an irreversible reaction and that we have come to stay.

The experiment, however, is by no means a modern invention. As early as the thirteenth century Roger Bacon was proclaiming to unsympathetic scholars its soundness as an instrument for the discovery of truth. In his opus majus he maintains that

There are two modes of knowing; by argument and by experiment. Argument concludes a question; but it does not make us feel certain, or acquiesce in the contemplation of truth, except the truth be also found to be so by experience.

And still farther on in the same work he declares that

Experimental science, the sole mistress of speculative sciences, has three great prerogatives among other parts of knowledge: First, she tests by experiment the noblest conclusions of all other sciences; next, she discovers respecting the notions which other sciences deal with, magnificent truths to which these sciences themselves can by no means attain; her third dignity is, that she by her own power and without respect of other sciences, investigates the secrets of nature.

Although Roger Bacon's utterances in favor of experimental science were made over three centuries before the days of his illustrious fellow countryman, Francis Bacon, and at a time when such utterances were dangerous, they were by no means the earliest expression of the experiment. Some sixteen centuries before Roger Bacon's time, Aristotle wrote in simple language an account of what is probably the